the center of gravity is at 39% of the length (measured from the nose). An ambient density of 0.18 kilogram per cubic meter of carbon dioxide (CO_2) is chosen so that the Reynolds number will be consistent with that for the full-scale entry body at Mars. A nominal launch velocity of 680 meters per second ensures Mach numbers ranging from 2.5 down to 2 as the model decelerates along the length of the test section.

Four tests were conducted at consistent conditions in order to reduce uncertainty in the estimated aerodynamic parameters. The results summarized in Table 1 confirm the stable behavior of the loaf-shaped vehicle. The experimental value of drag coefficient is lower than the computational fluid dynamic (CFD) estimate because it includes wake effects. Pitch and yaw coefficients also indicate a discrepancy that is up to 20% of the CFD estimate, which confirms that analysis of the forebody alone does not adequately predict aerodynamic behavior at low supersonic speeds. Uncertainty in lift coefficient is relatively high because the angle-of-attack variation was small in some tests.

Table 1. Aerodynamic parameters of bread-loaf geometry in supersonic speed range.

Parameter	Forebody CFD estimate	Ballistic range estimate
CD_0	1.6	1.381 ± 0.002
Cm_α	-0.208	-0.18 ± 0.01
Cn_β	-0.235	-0.28 ± 0.02
CL_α	-1.07	-0.80 ± 0.19

The results of this study indicate the feasibility of using a loaf-shaped entry vehicle which maximizes packaging capability for the Ariane V launch vehicle. If this shape is selected for future missions, additional tests and full-body CFD analysis should be performed to model the detailed flow more accurately and to reliably define the vehicle aerodynamic coefficients.

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Aerothermal Analysis of X-33 Elevon Control Surface Deflection

Dean Kontinos, Dinesh Prabhu

As the X-33 nears final construction, the analytical emphasis has been redirected from generating design data to mitigating flight risk. Computational simulation of the flow field surrounding deflected elevon control surfaces has been performed to verify engineering estimates of the heating levels that the canted fin must be designed to withstand. This analysis serves to reaffirm design assumptions and reduce uncertainty, thus decreasing flight risk.

In previous simulations, surface heating predictions were based on the assumption of a smooth body. In reality, the body surface has both protuberances, such as steps and gaps formed between seals or tiles, and control-surface deflections that divert the flow from its nominal path. These surface irregularities and control-surface deflections trigger local fluid mechanical interactions that increase the heat transfer in some zone of influence on the surface. The thermal protection system is designed to account for these local effects by applying multiplicative scale factors, derived through empiricism and theory that augment the baseline smooth-body heating levels.

To validate the design correlations, computational fluid dynamics (CFD) techniques have been used to simulate the flow field around deflected elevon control surfaces. The geometric model includes the gap between the elevon control surface and the main body, the gap between the elevon surfaces, and the abbreviated edge of the elevon at the tip of the canted fin. Figure 1 shows radiative equilibrium surface temperature contours on the windward side of the X-33, along with an expanded view of the deflected elevon surfaces. The flow conditions are Mach 10, an angle of attack of 30 degrees, an altitude of 180,000 feet, and elevon control-surface deflection of 25 degrees. Evident in the figure is the increased heating on the face of the elevon generated by its deflection into the hypersonic flow field. Also discernible is increased heating on the sides of the elevon caused by the flow accelerating around the edges of the control surface. The maximum elevon surface temperature occurs in the gap region. These results are being used to verify the suitability of the design.

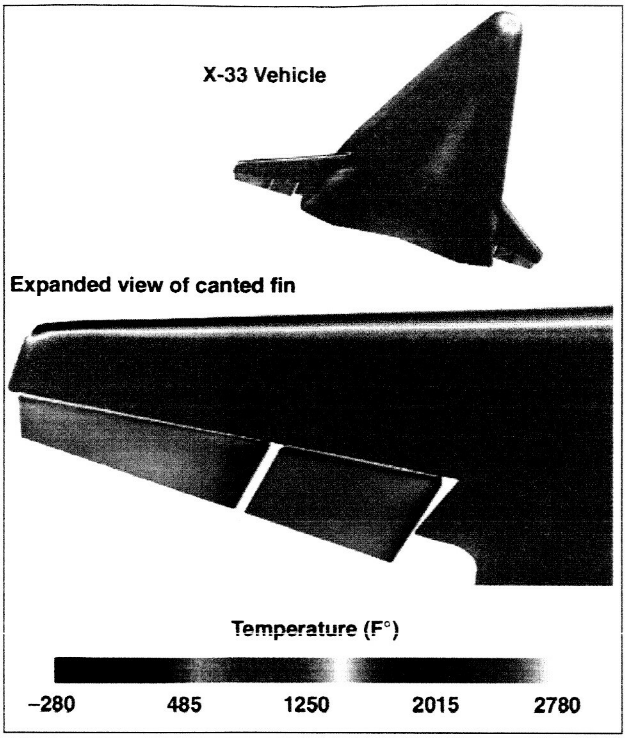

Fig. 1. Computed radiative equilibrium surface temperature contours on the X-33 vehicle with the elevon control surface deflected 25 degrees at Mach 9, an angle of attack of 30 degrees, and an altitude of 180,000 feet.

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CFD Analysis of Arc-Jet and Flight Environments for the B-2 Flight Experiment

Mark Loomis, Grant Palmer

Ames Research Center has been developing new ultrahigh temperature ceramics (UHTC) for potential use in the sharp leading edges of future space vehicles. These materials have been developed and tested in ground-based arc-jet facilities, and a flight test program called SHARP (slender hypervelocity research aerothermodynamic research probes) has been initiated. The first flight demonstration, SHARP-B1, incorporated a 0.141-inch-radius UHTC nose-tip on a U.S. Air Force reentry vehicle in collaboration with Sandia National Laboratory; it was successfully flown in May 1997. The second flight test, SHARP-B2, incorporates four instrumented UHTC strakes mounted on the side of the entry vehicle; it is scheduled to fly in June 2000. The goal of these flight tests is to assess the performance of the materials under realistic entry conditions.

Computational fluid dynamics (CFD) simulations of the flight environment have been performed to aid in the design of the test hardware and instrumentation, and simulations of critical qualifying ground tests in the arc-heated wind tunnels have been performed to aid in test interpretation and instrument checkout, and to show traceability of the ground-test environment to flight.

Figure 1 shows computed heat-transfer profiles on the surface of the flight vehicle and the test article in the arc-heated wind tunnel. Although simulation of the complex-flow physics in the arc-heated wind tunnel is difficult, the goal of the simulations is to understand the flow environment well enough that the similarities and differences in the flight conditions can be assessed. Initial comparisons between the CFD and arc-jet data are generally within 40% for heat transfer and 5% for pressure, giving some confidence in the predictive method. The CFD predictions will be compared with flight results once they are available.

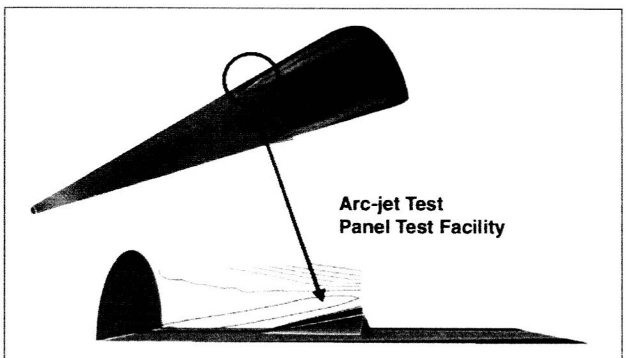

Fig. 1. Heat-transfer profiles for flight vehicle and test article. Flight: Modified MK-12 RV launched on Minuteman III.

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